MT 8704 Agriculture

Soil Testing Procedures, Interpretation and Fertilizer Sources

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Soil tests provide a chemical estimate of nutrient availability and a sound basis to predict crop response to fertilizer. Soil tests are valuable fertility management aids to increase on-farm productivity and profits. Soils testing low in fertility require fertilizer materials and/or crop rotations to supply plant nutrient requirements. Soils testing high in certain nutrients can supply 100 percent of the crop requirement, and no fertilizer is needed. Amounts of essential elements required for optimum growth vary with the crop, yield, soil and environment. Improper use of soil test results may lead to increased production costs with yield and quality losses or related problems. No substitute exists for reliable, continuous soil testing in a complete fertility management program.

Meaningful soil test results for fertilizer recommendations depend upon samples properly taken and prepared, correct laboratory analysis, good field calibration data and proper interpretation. Soil test results and other information will help answer the questions "Should I fertilize?" and if so,"How much fertilizer should I apply?" This information may include previous fertilizer practices, crop response, estimated yield potential, crop value, fertilizer cost, management ability and suggestions of other farmers, fertilizer dealers, Extension agents or soil scientists.

A soil test will be only as accurate as the sample submitted. Collecting a representative soil sample takes time and effort. Proper soil sampling technique is discussed in the MontGuide MT 8602 AG, "Soil Sampling." The next phase involves sample preparation, followed by laboratory determination of plant-available nutrient concentration. Determination of nutrient levels in a sample involves sample extraction, followed by analytical measurement. Plant nutrients extracted from the soil sample are related to crop uptake and response (soil test correlation).

Researchers and soil testing laboratories have developed tests calibrated for soils of their particular area. However, the tests may not be adaptable to a different soil or location. Each laboratory's fertilizer recommendations relate to its analytical procedures, interpretation and overall approach. Therefore, Montana samples should be submitted to a laboratory that uses analytical techniques recommended by Montana State University. This provides the best chance of obtaining analytical results for fertilizer recommendations calibrated in Montana.

Producers should keep records to evaluate the accuracy of recommendations and to adjust fertilization programs to account for specific cropping and management practices.

Soil samples are routinely evaluated for pH (acidity or alkalinity), organic matter, electrical conductivity, nitrate-nitrogen (NO_3-N), phosphorus (P) and potassium (K). Calcium (Ca), magnesium (Mg), sulfate-sulfur ($S0_4$-S), zinc (Zn), manganese (Mn), boron (B) and sodium (Na) can be analyzed when a specific problem is suspected. A brief description of each test follows.

Table 1. Relative tolerance of crops to salt[1.]

Electrical conductivity mmhos/cm	Description	Relative crop salinity tolerance
0–2	Nonsaline	All crops and vegetables should grow well
2–4	Slightly saline	Fieldbeans, radish, celery, green beans, meadow foxtail and White Dutch, Alsike, Red and Ladino clovers
4–6	Moderately saline	Small grains, alfalfa, sweet clover, most grasses and most other vegetables
8–16	Strongly saline	Barley, sugarbeet, tall wheatgrass, Canadian wildrye
> 16	Extremely saline	Few crops, alkali sacaton, saltgrass and Nuttall alkaligrass

[1]*Source:* Diagnosis and Improvement of Saline and Alkali Soils, *1954. USDA Agriculture Handbook 60. U. S Government Printing Off ice, Washington, DC.*

pH

Soil pH influences nutrient availability and crop growth. A 1:1 soil-to-water suspension is recommended for Montana soils. A soil pH of 7.0 (neutral) is used as a standard to categorize soils as acidic (pH less than 7.0) or basic (pH greater than 7.0). A pH range of 6.5 to 7.5 is considered favorable for most Montana field crops, although soils outside this range are productive. Soil pH, a measure of hydrogen ion activity, is expressed in logarithmic form. Therefore, the alkalinity or acidity changes by a factor of 10 for each full soil pH unit (for example from 5 to 6). Acid soils below pH 6.5 may need lime for alfalfa or sweet clover. Some soils have pH values from 7.5 to 8.4, which decreases the availability of micronutrients. Soils may be sodic (excess sodium) when the soil pH is above 8.4.

Organic Matter (O.M.)

Organic matter has been used as an indicator of soil productivity. This relates directly to the release of nitrogen and other nutrients through the decomposition of plant, animal and microbial materials. With continued cultivation and cropping, organic matter levels declined, so that nitrogen must be supplied through fertilizer or crop rotations. Organic matter decomposition releases nitrogen, phosphorus, sulfur, boron and zinc; increases exchange capacity; provides energy for micro-organism activity; and releases carbon dioxide. Organic matter in the soil increases water-holding capacity, stabilizes soil structure and improves tilth and buffer capacity. Adequate organic matter levels reduce soil compaction, water infiltration and surface crusting problems. Soil texture and organic matter content also influence application rates and decomposition of soil-applied pesticides.

Electrical Conductivity (E.C.)

Electrical conductivity of a soil extract measures soluble salt concentration and salt hazard to crops. Crops grown at salt levels (saturated paste) indicated in Table 1 may show some yield reduction.

Nitrogen (N)

The nitrogen soil test measures the amount of plant-available NO_3-N at time of sampling. Nitrogen, as NO_3-N, is highly soluble and moves through the profile under high precipitation or irrigation. The crop's nitrogen requirement depends upon the estimated yield potential for dryland small grains, based upon the amount of actual soil-stored and anticipated (growing season precipitation) water. Additional factors that determine nitrogen fertilizer requirement include management ability, crop quality, local environment, soil, variety, historical yields and related production factors. A "budget approach" determines the actual fertilizer requirement and can be obtained by subtracting the pounds of NO_3-N (from soil test) in the soil from the total nitrogen requirement. Past cropping practices, manure, legume rotation, soil sampling depth, organic matter level and incorporation of crop residues all influence the nitrogen fertilizer requirement. Common nitrogen fertilizer materials and the composition of manures are presented in Tables 2 and 3.

Table 3. Composition of manures and waste materials

	Percent	N		P_2O_5		K_2O	
Source	Moisture	%	lbs/tn	%	lbs/tn	%	lbs/tn
Beef feedlot	68	0.71	14.2	0.64	12.8	0.89	17.8
Dairy	79	0.56	11.2	0.23	4.6	0.60	12.0
Liquid dairy	91	0.24	4.8	0.05	0.1	0.23	4.6
Swine	75	0.50	10.0	0.32	6.4	0.46	9.2
Liquid swine	97	0.09	0.2	0.06	0.1	0.08	0.2
Horse	70	0.69	13.8	0.23	4.6	0.72	14.4
Sheep	65	1.40	28.0	0.48	9.6	1.20	24.0
Poultry (no litter)	54	1.56	31.2	0.92	18.4	0.42	8.4
Liquid poultry	92	0.16	3.2	0.04	0.8	0.29	5.8

Table 2. Composition of nitrogen, phosphorus and potassium fertilizer sources[1].								
Fertilizer Materials	**% Total Nitrogen (N)**	**% Available Phosphorus (P_2O_5)**	**% Water Soluble Potassium (K_2O)**	**% Calcium (Ca)**	**% Sulfur (S)**	**Equivalent Acidity or Basicity[2] lbs $CaCO_3$ Acid**	**Base**	**Salt Index[3]**
Nitrogen								
Ammonium nitrate, NH_4NO_3	33.5–34					62		104.7
Ammonium nitrate-sulfate $NH_4NO_3 \cdot (NH_4)_2SO_4$	30				6 5	68		
Monoammonium phosphate $NH_4H_2PO_4$	11	48				58		34.2
Ammonium phosphate-sulfate $NH_4H_2PO_4 \cdot (NH_4)_2SO_4$	16	20			15	88		
Ammonium phosphate-nitrate $NH_4H_2PO_4 \cdot NH_4NO_3$	27	12			4.5	75		
Diammonium phosphate $(NH_4)_2HPO_4$	16–18	46–48				70		29.9
Ammonium sulfate, $(NH_4)_2SO_4$	21				24	110		69.0
Anhydrous ammonia, NH_3	82					148		47.1
Aqua ammonia, NH_4OH	20					36		
Calcium ammonium nitrate solution $Ca(NO_3)_2 \cdot NH_4NO_3$	17			8.8		9		
Calcium nitrate, $Ca(NO_3)_2$	15.5			21			20	52.5
Sodium nitrate, $NaNO_3$	16						29	100
Urea, $CO(NH_2)_2$	45-46					71		75.4
Urea formaldehyde (ureaform)	38					60		
Urea ammonium nitrate solution $NH_4NO_3 \cdot CO(NH_2)_2$	32					57		73.0
Phosphorus								
Single superphosphate, $Ca(H_2PO_4)_2$		18–20		18–21	12	neutral		7.8
Triple superphosphate, $Ca(H_2PO_4)_2$		45–46		12–24	1	neutral		10.1
Phosphoric acid, H_3PO_4		52–54				110		
Superphosphoric acid H_3PO_4, $H_4P_2O_7$, $H_5P_3O_{10}$ and higher phosphate forms		76–83				160		
Potassium								
Potassium chloride, KCl			60–62			neutral		115.3
Potassium nitrate, KNO_3	13		44–46				26	73.6
Potassium sulfate, K_2SO_4			50–53		18	neutral		46.1
Sulfate of potash-magnesia $K_2SO_4 \cdot 2MgSO_4$			22	0.1	22	neutral		43.2

[1]*Source Western Fertilizer Handbook, Seventh Edition, 1985. The Interstate Printers and Publishers, Inc., Danville, 61832-0594.*
[2]*Equivalent per 100 pounds of each material*
[3]*Measure of the salt contribution by a fertilizer material to that produced by an equivalent weight of sodium nitrate relative value of 100).*

Phosphorus (P)

The Olsen (sodium bicarbonate) phosphorus test provides an index of available soil phosphorus. The phosphorus index is NOT a measure of the pounds of phosphorus available per acre. Laboratory phosphorus analysis measures the soil's ability to supply phosphorus to the plant at a given time, but it is only a small fraction of total soil phosphorus. Available phosphorus levels, determined by soil tests, do not vary widely from year to year and tend to be characteristic of individual fields and soils. Phosphorus is relatively immobile in the soil, so proper placement of phosphorus fertilizer is important. Phosphorus fertilizer sources are provided in Table 2.

Potassium (K)

Potassium soil tests, like phosphorus soil tests, provide an index of available potassium. Ammonium acetate is the extracting agent. Available potassium is present in the soil solution and is loosely held in exchangeable form on clay particles and organic matter. Although considered immobile in the soil, potassium is somewhat more mobile than phosphorus. Crop responses to potassium have been observed on soils determined by soil tests to have adequate levels. Recent research indicates that cold, dry conditions limit the soil's ability to "resupply" adequate potassium for plant requirements. Because growing season conditions and soils greatly influence potassium availability, guidelines for application of potassium have been somewhat difficult to establish for Montana soils. Potassium fertilizer sources are shown in Table 2.

Calcium (Ca), Magnesium (Mg) and Sodium (Na)

Calcium and magnesium are classified as secondary nutrients, while sodium is a nonessential nutrient. An ammonium acetate extract soil test measures the readily-extractable (soluble and exchangeable) portion of soil solution nutrients that are loosely held on clay particles and organic matter. Calcium and magnesium deficiencies have seldom been observed in Montana due to extremely high native soil concentrations. Calcium, magnesium and sodium determinations help evaluate potential sodium hazard. See MontGuides "Saline and Sodic Soils in Montana" (MT 8372 AG), "Managing Dryland Sodic Soils" (MT 8381 AG), and "Salinity Control Under Irrigation" (MT 8382 AG) for further information.

Table 4. Composition of boron, copper, iron, manganese, molybdenum and zinc fertilizer sources.

Fertilizer Sources	% Element	—Water Solubility— lbs/10 gal H2O	g material/ 100 g H2O
Sources of boron			
Granular borax, $Na_2B_4O7 \cdot 10H_2O$	11.3	2.1	2.5
Sodium tetraborate, anhydrous $Na_2B_4O_7$	21.5	1.1	1.3
Solubor, $Na_2B_8O_{13} \cdot 4H_2O$	20.5	18.4	22
Ammonium pentaborate $NH_4B_5O_8 \cdot 4H_2O$	19.9	5.8	7
Sources of copper			
Copper sulfate, $CuSO_4 \cdot 5H_2O$	25.0	20	24
Cuprous oxide, Cu_2O	88.8	insoluble	
Cupric oxide, CuO	79.8	insoluble	
Cuprous chloride, Cu_2Cl_2	64.2	1.25	1.5
Cupric chloride, $CuCl_2$	47.2	59	71
Sources of iron			
Ferrous sulfate, $FeSO_4 \cdot 7H_2O$	20.1	27.5	33
Ferric sulfate, $Fe_2(SO_4)_3 \cdot 9H_2O$	19.9	367	440
Iron oxalate, $Fe_2(C_2O_4)_3$	30.0	very soluble	
Ferrous ammonium sulfate $Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$	14.2	15	18
Ferric chloride, $FeCl_3$	34.4	61.8	74
Sources of manganese			
Manganous sulfate, $MnSO_4 \cdot 4H_2O$	24.6	87.6	105
Manganous carbonate, $MnCO_3$	47.8	0.0054	0.0065
Manganese oxide, Mn_3O_4	72.0	insoluble	
Manganous chloride, $MnCl_2$	43.7	52.6	63
Manganous oxide, MnO	77.4	insoluble	
Sources of molybdenum			
Sodium molybdate $Na_2MoO_4 \cdot H_2O$	39.7	46.7	56
Ammonium molybdate $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$	54.3	36.7	44
Molybdic oxide, MoO_3	66.0	0.9	0.11
Sources of zinc			
Zinc sulfate, $ZnSO_4 \cdot H_2O$	36.4	74.3	89
Zinc oxide, ZnO	80.3	insoluble	
Zinc carbonate, $ZnCO_3$	52.1	0.0008	0.001
Zinc chloride, $ZnCl_2$	48.0	360	432
Zinc ammonium sulfate $ZnSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$	16.3	8	9.6
Zinc nitrate, $Zn(NO_3)_2 \cdot 6H_2O$	22.0	270.4	324

Table 5. Composition of additional sources of sulfur.

Sulfur Materials	% Sulfur
Elemental sulfur	99
Gypsum	16–18
Sulfuric acid (95-99%)	32
Ferrous sulfate	11.5
Ferric sulfate	18–19
Calcium polysulfide solution	25
Ammonium polysulfide solution	40–45
Ammonium bisulfite solution (8.5% N)	17
Ammonium thiosulfate solution (12% N)	26

Sulfur (S)

No reliable soil test for sulfur is available. Organic matter, gypsum, rainfall and other soil minerals are the primary sources of sulfur in Montana soils. Sulfate-sulfur ($S0_4$-S) is soluble and moves in the soil, but less readily than NO_3-N. Forages, particularly alfalfa, require high sulfur levels compared to small grains. Deficiencies may develop in some low-organic-matter, sandy soils heavily fertilized with nitrogen and in high rainfall or irrigated areas. Although sulfur deficiencies are not common in Montana, application rates of sulfur between 10 to 40 pounds per acre have been effective in very isolated areas. Common sources of sulfur are presented in Tables 2 and 5.

Zinc (Zn), Iron (Fe), Manganese (Mn) and Copper (Cu)

Availability of these trace or micronutrients can be estimated from soil tests using a DTPA extract. High soil pH decreases availability of these micronutrients, causing isolated deficiencies on some soils with certain crops, but micronutrient deficiencies are not frequent in Montana. Corn, sorghum, sudan, beans and potatoes require higher zinc levels than other crops. Zinc deficiencies are corrected by applications from 2 to 15 pounds of zinc per acre, depending upon soil test results. Other crops, such as small grains, alfalfa and grasses, respond infrequently to zinc applications. Sorghum, field beans and corn are the field crops most susceptible to Fe deficiency. Iron-deficient soils can be corrected by dissolving 20 pounds of iron sulfate in 100 gallons of water and applying to foliage at 10 to 20 gallons per acre. Small grains, corn and beans require higher manganese levels. Field responses to manganese or copper have not been documented in Montana. Critical soil test levels for these micronutrients are shown in Table 6. Foliar application of fertilizer materials can effectively correct micronutrient deficiencies. Micronutrient fertilizer sources and chelates are presented in Tables 4 and 7.

Table 6. Critical micronutrient soil test levels for Montana soils.

Element	Low (inadequate)	Medium (marginal)	High (adequate)
	parts per million (ppm)		
Zinc	0–0.5	0.5–1.0	> 1.0
Iron	0–2.5	2.5–4.5	> 4.5
Manganese	0–1.0	—	> 1.0
Copper	0–0.2	—	> 0.2

Boron (B)

The boron soil test utilizes hot water extraction. Plants usually obtain adequate boron from subsoil or irrigation water to achieve optimum yields. Alfalfa and sugar beet are most susceptible to boron deficiencies. Application of 1 to 3 pounds of boron per acre is common when soil tests indicate deficiencies. Special precautions should be taken with boron application, because the difference between toxic and adequate levels for different crops is very narrow. Avoid contact with the seed. Boron fertilizer sources are presented in Table 4.

Molybdenum (Mo) and Chloride (Cl)

Plant requirements for molybdenum and chloride are low. Responses to chloride of 3 to 7 bushel per acre have been documented in Montana. Consider said test to document deficiencies.

Fertilizer Sources

Many fertilizers sources are currently available to meet plant nutrient requirements, based on soil test results, and are listed in the various tables.

Table 7. Composition of synthetic chelates for supplying micronutrients

Chelating Agent	% Micronutrient Element Cu	Fe	Mn	Zn
EDTA	7–13	5–14	5–12	6–14
HEEDTA	4–9	5–9	5–9	9
NTA	—	8	—	13
DTPA	—	10	—	—
EDDHA	—	6	—	—

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